Chapter 1

Foundations of Physicality with Deterministic Modified Qubit Mechanics

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We explain our mechanics for deterministic physicality, encoded formally as a set of six rules, taking a journey from nothing to dynamic physical systems. On the way, we show how the rules encode many principles we rely upon in physics and philosophy, such as uniqueness, exclusion, propagation, physical reification, and how physical networks emerge from basic dynamics. We also summarize the emergent phenomena, and how we observe them from a human perspective.

1. Introduction

1.1. *Deterministic rules*

Since 2012,[1] our papers have started with our six rules, which we described as minimal and necessary for physics to emerge:

(1) Waves are bound in pairs as oscillators or qubits.

(2) Waves propagate radially, as light speed bosons, having first-order equivalence of phase, distance, and time:

$$d\phi = ds = dt \tag{1}$$

(3) Nonunique waves, having the same phase and source, are excluded from interactions.

(4) An oscillator's mass is its elliptical skew:

$$\rho = e^{-i(\phi_B - \phi_A)} \tag{2}$$

(5) ρ modulates phase ϕ of other overlapping waves.

(6) Two waves, from different fermions, with $\phi = 0$ at a unique point, collapse their oscillators into a **fermion**.

1.2. *Science communication*

The philosophical reasoning and purpose for these rules can be arbitrary for a reader, so whenever we have presented this mechanism to an audience,[3] we briefly outlined the foundations to show that the work is supported by information theory, and as a useful justification for the rules. In this paper, we take a guided journey through those foundations.

As authors, we found this paper difficult to write. We wanted to start from nothing, adding minimal structure for each conceptual step on the journey to building a complete physical system. However, when we assumed the role of fresh readers, imagining what we had described, we found that the reader brought too much of their own human experience with each concept we introduced. For example, if we begin with only a single entity, a reader might typically imagine a dot nearby in space, which is already too much physical context, because there is no space and no localization of state. To help avoid this, we take care to explain what we have and do not have at any given stage of our journey.

Another challenge is that the mechanism only makes physical sense as a whole, rather than to introduce parts of the structure one by one, so as we add to the picture, our journey is abstract and hypothetical. Our journey illustrates that some principles emerge from a subset of our rules. One point of our journey unlocks most of the mechanism at once, including dynamics, but our writing is linear so we must pause to describe those implications.

1.3. *Outline*

We start with a minimal description of an entity, and methodically build in more features that allow entities uniqueness and connection to other entities, an emergent background, and dynamic systems. We then distinguish between physicality, and the background processes and states that nothing can directly interact with, and create a picture of emergent reality.

2. Entity to plurality

2.1. *Entity*

Given that we are describing physics, there needs to be a definition of what 'something' is. Our description begins by asking how an entity may be minimally described. We then require a means for multiple entities to exist and to be uniquely reconciled among themselves.

2.1.1. *Attribute*

We start with simplest form of '*not* void', an unassigned **attribute**. It has no structure and it is the only instance of entity. Technically, 'entity' might be a poor label, but it will become more correct as we progress. There is no space in which we can say there *is* entity or there is *no* entity, because the entity is not localized.

As we will find on the first few steps of this journey, this entity is not a physical system. There is no variation, no medium, and no 'otherness' or relative state to observe. It will only become a physical system when there are many entities and a means for them to interact.

2.2. *Spectrum and multiple values*

2.2.1. *Value*

Let's assign a **value** of 0 to the attribute. Mathematically, **zero** assumes a basis axis and a value on that axis, such as $y = 0$, which requires trivial geometry. A value always has context, such as a value of an attribute of something, so it may only apply where there is entity. At this stage, we could ignore the value, because it has no wider meaning yet, but we will use the value later.

Because we lack a space or domain, we are not yet ready to describe this as a homogeneous scalar field.

2.2.2. *Uniqueness and spectrum*

To usefully approach a physical system like the one we inhabit, we need to incorporate more entities. If there were a means for comparison and identity, which we do not yet have, then for entities to be separably identifiable, there must exist some difference between them. Without this **uniqueness** as a means for entities to be identified and addressed, entities cannot interact.

> An entity may co-exist with other entities only if its state is different from the states of all the other entities.

We may quantify the possible unique states by introducing the concept of **spectrum**: the set of possible values that a state may have. With one attribute to represent state, states may not exist if they have the same value in that attribute.

For example, if entities have a state spectrum of two possible values (fig.1), then two entities may exist (fig.1, **C**) provided they have different state values. These two entities have no mechanism for interaction, and there is no concept of intrinsic and extrinsic, so there is no means to know they exist, and their number and state are meaningless.

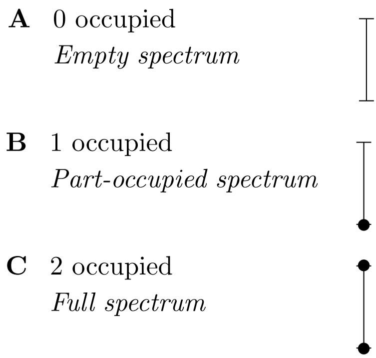

Fig. 1. Filling a spectral capacity of two available states.

With those options exhausted, no further entities may be introduced to the system because they cannot be unique, and we need an alternative means of including more (fig.2):

- Increase the number of attributes per entity.
- Increase the number of available states per attribute.
- Use a continuous, not discrete, attribute.

3. Exclusion, locality, dynamics

So far our picture is static and non-local. Many states may exist at one single point, without there being any need for anything to exist outside that point. Indeed, the notion of a point is not yet important, and a whole manifold, if there is one, is covered by all entities with there being nothing to uniquely identify any part of the space as being different from any other. Again, we are missing some mechanics, and the states do not relate to each other in any way.

For a system that has multiple entities of the same value, we need instancing, which creates entities that may have identical values of attributes,

D 2 attributes per entity
4 unique combinations
Full spectrum

E 4 available states
Full spectrum

F Infinite available states
Infinite entities possible

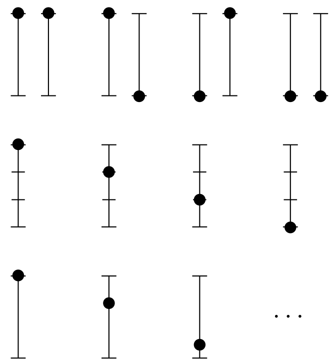

Fig. 2. Options for increasing spectral capacity.

but still be unique in another degree of freedom. This is like invoking option **D** (fig.2). However, we still have no mechanics for these entities to interact.

> An entity may exist in the same system as other entities only if its is unique in all degrees of freedom.

If we use option **F** (fig.2) to allow a state to have any continuous value, we could introduce a mechanism to push an attribute value away from its initial state, on that continuous spectrum, to connect with another entity. However, while we want entities to connect (or couple or interact), we need another means of uniqueness, because if we vary the value, it might equal another value within the entity, and become indistinguishable.

We need to regard the push as:

- **Continuous**, so we require no incremental action for the change.
- **Connectable**, so an instance can replicate state.
- A **degree of freedom**, or a way of creating another attribute or instance for uniqueness, as option **D** (fig.2).

3.1. *A wave*

A sinusoidal **wave** can satisfy all these requirements. It is continuous and allows revisiting of a previous attribute value.

Identical entities are now allowed, but not at the same point on the wave, which permits multiple instances along that wave.

We can regard this wave as space-like to imply that the instances on the wave are clones in a spatial crystal, or we could regard the wave as time-like to imply the instances are the same entity at different times. We choose time-like, because it relates to our human experience, and gives us first-order differential calculus when we think in terms of Nöether's Theorem to identify dimensions that change and dimensions that do not change.

This introduces:

- **Phase** propagation, as a fundamental change for the wave state, closely related to its value as a function of the phase.
- **Time** as a nonlocal and universal expression of phase propagation.

This implies **universal equivalence** and the basis for rule 2 (1.1):

> Phase propagation acts universally for all entities.
> Time propagation is equivalent to phase propagation.
> **Space** is an offset equivalent to the phase offset and the time offset.

This means that all entities propagate, and phase has the same meaning for all waves. Consequentially all waves propagate similarly. When related to classical or relativistic space, we know this as 'light speed propagation'.

3.2. *Matter networks*

This push or displacement introduces new properties for the system:

- **Locality**, because the phase offsets create an implicit spatial offset.
- **Causality**, because events are connected as being the same entity, in a time-like sequence through the offset. This is not sufficient for full causality, which requires networks (3.3).

3.2.1. *Connectedness and similarity of entities*

We distinguish between **connected** and **similar** states (fig.3):

- $\{\mathbf{A}\}$: Reference.
- $\{\mathbf{A}, \mathbf{B}\}$: Disjoint.
- $\{\mathbf{A}, \mathbf{C}\}$: Connected.
- $\{\mathbf{A}, \mathbf{D}\}$: Similar.
- $\{\mathbf{A}, \mathbf{E}\}$: Similar and connected.

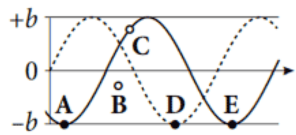

Fig. 3. Connected and similar states

Specifically, we take one entity **A** as 'base state' and another entity **E** as 'state **A** + phase operator f', where both entities would be identical if they were resolved through phase operator f to the same point: $f\mathbf{A} = \mathbf{E}$. This identies two spacetime coordinates as being on the same world line.

Similar states are not necessarily directly connected, but have the same states in different localities or times. For example, in fig.3, $\{\mathbf{A}, \mathbf{D}\}$ are similar, and $\{\mathbf{A}, \mathbf{E}\}$ are similar and connected.

This illustrates that the latent phase offset allows multiple copies of a variable to exist with the same value in different places.

3.3. *Implied background space*

The phase offset implicitly creates a background space, but minimal systems will not create the 3D Euclidean space that we recognise in classical physics. Instead, each entity is regarded as having a fundamental phase offset from at least one other entity, so any background space is derived from these intervals, rather than the intervals being defined by the entities' positions in the background space. 3D space is just a generalization of the simplest reduction of larger systems, and time is a generalization of phase propagation.

However, we should be alert to the consequences of assuming a $(3, 1)$ metric, whereas the phase offset is more fundamental. We might be surprised by 'quantum weirdness' if we assume the fixed metric.

3.4. *Unambiguous connection: unique solvability*

In having two entities, their attributes should make them unique, otherwise they will look like one entity, or be undetectable. Therefore, for entities to interact, they need to be distinguishable in at least one attribute. This is another way of saying that for one entity to interact with another, the values of the other entities within scope must be unique.

Assume there are three entities. Given these three entities, they must somehow relate to each other. For three entities $\{\mathbf{A}, \mathbf{B}, \mathbf{C}\}$, there are three pairs:

- **A** must relate to **B**,
- **A** to **C**,
- **B** to **C**.

We require uniqueness. If **A** is the same as **B**, then **C** will not be able to tell them apart, and if we require a relation between entities to return only one solution, then all connected entities must be uniquely resolvable to each other.

In our mechanism, we do not require $\{\mathbf{A}, \mathbf{B}, \mathbf{C}\}$ entities, but instead require connected events, which might be time-displaced versions of the same entities.

3.5. *Coupling oscillators as fermions*

We can construct oscillators by requiring that an entity be formed of two waves, which we can regard as a reference wave and an order term offset by a quarter cycle that conserves angular momentum. However, each wave in this pair is as fundamental as the other, so it is better regard this as a superposition of states, but neither priviliged until one of them interacts, as determined elsewhere on the network. The oscillator structure also gives us two attributes that contribute to their uniqueness.

For the oscillators to interact with other oscillators, they should connect, which requires them each having a wave state with the same value. However, the order terms of both oscillators must be unique, or the oscillators themselves will have no unique identity.

Coupling is a uniqueness condition where a wave from each of two oscillators is identical in value and other degrees of freedom, but their order waves differ. This coupled state is a **fermion**, and in any other condition, entities are part of a bosonic state.

This gives us rule 6, as a way of solving the **measurement problem**:

> Two waves, from different fermions, with $\phi = 0$ at a unique point, collapse their oscillators into a **fermion**.

3.6. ***Radiation***

Fermions do not remain at a position; they immediately deconstitute and radiate, and always at light speed. Given that this is fundamentally a phase offset, expressed as both a time and space offset, we can generalize this in 3D flat space as a spherical propagation at light speed. These radiating **shells** may collapse into fermions when they meet other shells, localizing the entities, and the collapsed shells then re-radiate from the new locality. A **matter network** is comprised of these radiation and collapse cycles.

3.6.1. *Entropy and thermodynamics with the propagation geodesic*

In terms of propagation, light-speed radiation is the default condition, until the shell is collapsed by another shell. Implications:

- Propagation is a geodesic in spacetime, without needing a force to cause action, similar to gravitation being a factor in the natural geodesic for curved spacetime in general relativity.
- Propagation is inherently thermodynamic, because the default behavior of a fermion is to radiate away in bosonic state. We could re-base thermodynamics with these quantum foundations.
- At regular Planck-length intervals, each wave has opportunity (fig.10) to interact with an external shell. We can derive entropy functions from outcomes of these opportunities.[1]
- The expectation value for particle radius is related not directly to mass, but to the intrinsic mass-energy encoded in its bosons, and vacuum flux density, which determine macro structural behaviors like momentum, inertia, gravitation, and charge.

3.6.2. *Vacuum*

This radiation, if not collapsed in the locality, continues to propagate in phase, which we can interpret as propagating into the surrounding space. Many such bosons that we do not account for in organized collections of matter are collectively **the vacuum**. As an environment that has vacuum energy, we model the vacuum as many such oscillators that radiated from previous fermions.

The distinction between matter and vacuum is merely a human perspective on what we regard as classical objects and what we regard as environment, but fundamentally we regard matter and vacuum to be different classes of arrangements of the same bosons; instances of discrete vacuum energy have the same basis as the objective fermions of interest.

3.7. *Exclusion*

An entity cannot receive two identical signals about other entities. Likewise, two entities sharing the same point may not share the same state values. As the oscillators propagate from a coupling, some waves are identical and cannot uniquely address the network. These are **excluded** from interactions. Other waves are not identical and are **available** for interaction (fig.4).

Immediately after every fermion, the shell always contains excluded and available waves. On every shell is an even number of available waves.

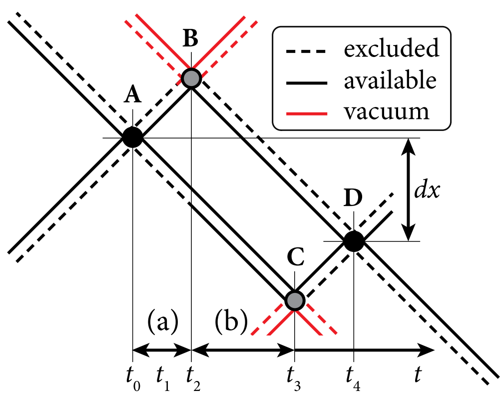

Fig. 4. The propagation of a conserved fermion from **A** to **D**. Each line is a wave; each pair of lines is an oscillator, as a boson.

3.7.1. *Weak interaction*

Rather than considering the weak interaction as a distinct field, we identify it as the possible changes in the potential of the expanding shell. Component waves of Z and W bosons are spread over all oscillators in the shell, and the waves may collapse independently to change the potential.[4]

3.8. *Uniqueness in the matter cycle*

Fermions are a special condition on the continuous journeys of oscillators. Their uniqueness properties change through the fermion event (table 1).

Table 1. Uniqueness properties before, during, and after fermion events.

Property	Bosons to collapse	Fermion	Emitted Waves
Position	Ambiguous (many shells)	Unique	Ambiguous (on-shell)
Origin	Multiple points	Collapse point	Common point
Wave phase (collapsing)	Proximate	Identical	Excluded
Wave phase (partner)	Distinct	Unique	Available
Entanglement	Not entangled	Coupled	Entangled

3.8.1. *Reification through the discrete and the continuous*

Our mechanism has continuous waves, bound as oscillators, on bosonic shells. The waves remain in continuous phase propagation through a fermion event, but a fermion event is itself a discrete point manifestation of the contributing waves. It localizes the waves to a point, from which the entity radiates as bosons.

This differs from the standard interpretations, which use bosons as force-carriers between fermions, where bosons carry differences between fermions. The classical propagation of fermions is problematic at small scales, and we cannot assume a continuous propagation of a fermion along a vector, because in the quantum interpretation fermions seem to inexplicably leap without interactions in the intermediate space.

Our interpretation offers both classical and quantum, because the fermions *are* the bosons, propagating continuously and classically as spherical waves, and not in a strictly vector trajectory in 3D space. The shell collapses in a special condition at a displaced location. The vector propagation is a deterministic consequence of the shell collapse, rather than a random quantum leap shaped by a wavefunction. Having said that, we may approximate any given physical state along with unknowns as a wavefunction, but this interpretation loses information.[2]

Given the waves can only collapse at fermion events, then as observers, we can only interact with matter at its fermion events, through the bosonic shells that collapse those fermion events. In this scheme, there is no passive observation, and observers are a part of the total system.

Although we interact with our surroundings by receiving and sending bosons, from our own fermions, it is only at fermions that events can occur. At other stages, the matter is unreachable, and is perhaps 'sub-physical' or 'unphysical' during most of its propagation (4.2).

Further, our mechanism provides a fix for the measurement problem by specifying the deterministic conditions required to collapse superpositions of states in shells.

3.9. *Mass, collapse, and gravitation*

We have not yet accounted for mass and how that affects the collapse of shells. Our mechanism, as described thus far, would rarely collapse shells when they touch, because the condition requires an exact phase match from two waves with different origins, at an exact point, which is too improbable a collapse condition to occur in a real space without some exacting setup.

In our understanding of physics, some entities can propagate longer distances, passing through other matter, and other entities tend to be more localized. Rules 4 and 5 describe how mass is encoded in the structure of oscillators. If oscillators have high mass value, they are less likely to pass through other shells and are more likely to collapse other shells.

> An oscillator's mass is its elliptical skew: $\rho = e^{-i(\phi_B - \phi_A)}$.
> ρ modulates phase ϕ of other overlapping waves.

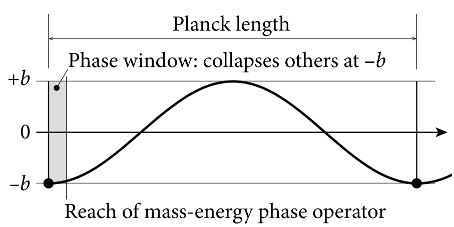

Fig. 5. This oscillator has a mass-energy that imposes a phase modulation on any overlapping boson, possibly triggering its collapse.

Modulation acts independently for each wave, so mass values are non-associative, so they do not accumulate, and positive and negative values do not cancel each other.

3.9.1. *Localization and particle size*

A conserved free fermion interacts with vacuum to reconstitute around the same area in space. We derive the 'size' of this fermion from the mass of the vacuum instances and the mass encoded in the fermion's shell.

The probability $P_H(r)$ of an expanding single-oscillator shell interacting with vacuum having uniform mass and phase distribution, where p is the proportion of the phase cycle available for interaction due to mass ρ,

$$P_H(r) = p^r(1 - (1 - p)^{\frac{dV(r)}{dr}}), \tag{3}$$

integrates to a 50^{th} percentile Compton radius,

$$r = \frac{\ln 2}{\rho}, \tag{4}$$

for non-overlapping phases of a shell.[1]

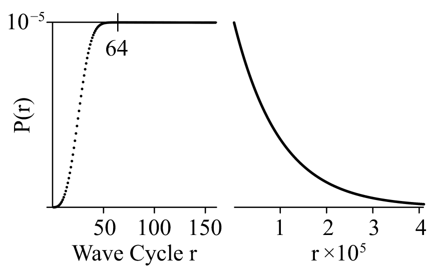

Fig. 6. Plot of eq.3, for $p = 10^{-5}$.

The profile of this interaction (fig.6) is asymptote-free, and contrasts with the standard inverse-power profile of charge and gravitation. This asymptotic freedom is distinct from the screening provided by exclusion. Our profile removes the ghost bosons required to explain deviations from singularities and asymptotes, and conveniently does not require renormalization. Without vacuum, an oscillator would propagate radially at light speed, and the probability of interaction with anything else does not diminish with radius. With vacuum, or any other trigger for wave collapse, the probability falls off with radius.

The asymptote-free profile also infers wells of 'lowest potential' for various phases, energies, and distributions of matter and flux. We can use these distances to infer parameters for our wave phases. We estimate these mass values, the free parameters of the mechanism, to have upper constraints of:[4]

$$
\begin{aligned}
A &\approx 4.0 \times 10^{-18} \\
B &\approx 2.9 \times 10^{-37}
\end{aligned}
\tag{5}
$$

3.9.2. *Gravitation and vacuum*

As with charge-based interactions, we represent gravitation as an attribution of flux origin, rather than a fundamental force.[4] A large classical body collapses and re-radiates vacuum oscillators, which may in turn collapse fermions some distance from the body. As with all collapse events, the positional solution of collapse is directly between the respective points of origin (fig.7).

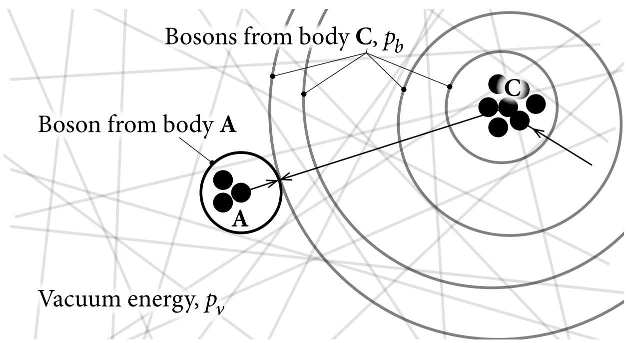

Fig. 7. Directional collapse between two classical sources.

Negative mass does not infer repulsion. Instead, it changes the absolute phase where $\phi = 0$, and also changes the sign of phase modulation imparted to other overlapping oscillators.

4. Observation and probability of reality

Our mechanism describes a fundamental reality that is hidden from human scale:

- We tend to observe the coherent massive fermions.
- There are limited opportunities for interaction within any significant span of time.
- We can only interact at a target's fermion events using bosons that our own fermions can interact with. There might be an intermediate

network between our probe or sensor and the target, or the target might be screened.

4.1. *Coherence*

A conserved coherent fermion interacts with its environment, and reconstitutes consitently. As observers, we might think it's exactly the same fermion, even if its lighter vacuum-contributed oscillators are interchanged with each interaction. As humans, we follow the 'objects', and the massive oscillator is the most localized and object-like in its expression, approximately confined to a region of space because its mass induces frequent collapse at short radius as it interacts with the vacuum. However, neither high-mass nor low-mass oscillators are privileged in the foundational processes.

4.1.1. *Annihilation and decay*

The mechanism demonstrates processes that we regard as important for the life cycle of objects and their transformations into other objects. These processes conserve the oscillators as information units, while creating objects that may be coherent for a span of time and annihilating them. These processes are accountable and deterministic, rather than spontaneous and random.

4.2. *Windows of opportunity*

Because of their encoded mass (eq.5), oscillators only have the opportunity to induce reification in a phase window (3.9) of up to 8×10^{-18} of the total wave cycle for the largest mass for quark-like entities, and up to 5.8×10^{-37} for neutrino-like entities.

For the remainder of the wave cycle, outside the interaction window for any given potential interaction between newly-touching shells is a significantly large interval that is out of reach for other entities, and for us.

For 99.9999999999999992% of the time, the universe is unphysical and out of reach. However, the human scale is relatively large compared with fundamental scales, so for any oscillator, the window of interaction occurs twice every Planck length (fig.10),[5] and there are 1.3×10^{36} opportunities per meter, or 3.8×10^{43} opportunities per second. To collapse, it must coincide in phase as it touches another shell in its respective window.

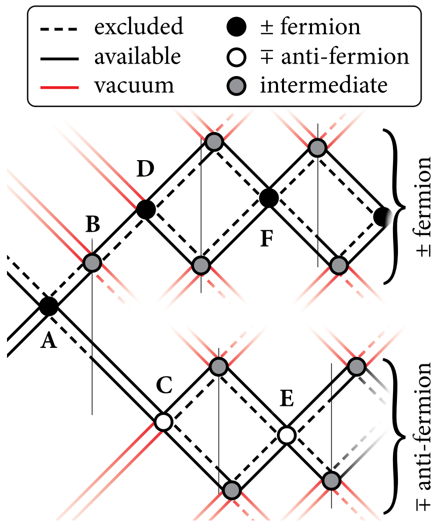

Fig. 8. A vacuum boson decays a previously coherent fermion **A** at fermion **B** into two coherent fermions **D**...**F**... and **C**...**E**....[2]

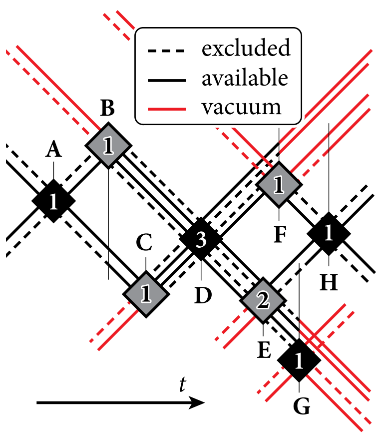

Fig. 9. Example decay of a 3rd generation fermion **D**. Numbers show fermion generation.[4]

Each active wave on the shell has a comb of impulses, and they are all interleaved, repeating every Planck length, offset from the origin.[2]

This appears to make matter unlikely to form from a random soup of oscillators. However, the Universe has been here a long time, and there have been many Planck-lengths (wave cycles) traversed by many bosons

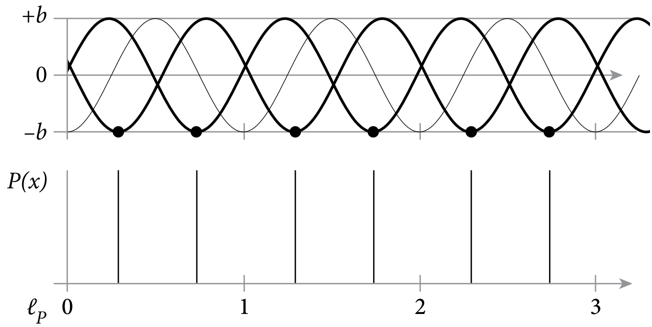

Fig. 10. With two active oscillators, opportunities interleave, and repeat every cycle. Two identical and excluded waves are shown as a thin line, and active positive and negative order terms as thicker lines

in high-temperature environments in that time, such that the quantity of observable matter is credible. The hadrons that exist now will have locked into a stable and robust reformation pattern that is mostly resilient to vacuum interactions. Still, with sufficient competition from the environment, hadrons can change their quark constitution.

4.3. *Screening*

In terms of which entities interact with other entities, some interactions are indirect. As a more relatable example, if you think you are touching a piece of iron, the electrons on your skin are interacting with the electrons of the iron block. Your interaction with the iron is indirect, and you do not directly touch the nucleus of an iron atom. Likewise, we should be aware of the interactions between more fundamental physical objects. Even at the scale of a single propagating fermion (fig.4), fermion components typically interact with the vacuum or other fermions via their virtual antifermion events **B** and **C**. Confined interactions are also possible, involving only a small set of fermions, and some of those fermions might have limited opportunities to interact with vacuum, such as hadrons.

Observations are only possible at fermion collapse events, but not for the intermediate sub-physical propagation. Indirect observation of fermion events is possible through a network of fermion events. For example, if the oscillators of a fermion are wholly conserved and confined over its propagation sequence $\mathbf{A} \rightarrow \mathbf{D}$ (fig.4), then any external sensing oscillators are interacting with the virtual antiparticles at **B** or **C**, or other wrappers of confined 'layers', rather than the fermion itself at **A** or **D**.

Observed properties (or net cross-sections) may vary according to the combinations of possible collapse sequences in the network, especially with 2nd and 3rd generation fermions.[4]

5. Conclusions

We created a minimal set of rules that offers an interpretation of physics at quantum and classical scales, and also offers foundations as a basis for quantum mechanics. The mechanism has a hierarchy of pertinent entity classes: pairs of waves bound as oscillators, entangled on bosonic shells, which then form a network of collapse events with other shells. This structure is repeatable across the extent of the Universe.

We offer a deterministic mechanism for the collapse of bosons into fermions that can appear random, with a clear understanding of point-like and wave-like properties at the stages of fermion propagation, which includes a way for the fermion to interact with its environment at a probabilistic radius as virtual antiparticles.

The mechanism also elegantly expands to the known Standard Model taxonomy and ontology,[4] with a deterministic basis for the statistical forces and fields of *quantum field theory* (QFT), and encodes gravitation into the same mechanism.[2] However, we do not claim a unified field, only a unified mechanism, and that the unification energy is at whatever radius the fermion can collapse, which is any length above $(0.25 - \rho)l_P$, repeating every Planck length, as $(n + [0.25, 0.75] \pm \rho)l_P$.[4]

We propose that the Planck length is the only length at which fundamental oscillators operate, and the emergent effects of that are why the Planck length is important in physics.

We can also speculatively interpret the effect of mass-based phase modulations as dilation of space or time, and the interactions with the vacuum flux to approach General Relativity.

Previously,[2] we offered interpretations of cosmological phenomena such as redshift, black holes, variable vacuum environments, and matter–antimatter asymmetry and polarization. We look forward to exploring other cutting-edge subjects with this mechanism, and invite others to try also.

A.1. Matter cycle as a process graph

We summarize the matter cycle of the mechanism as a process graph (fig.A.1).

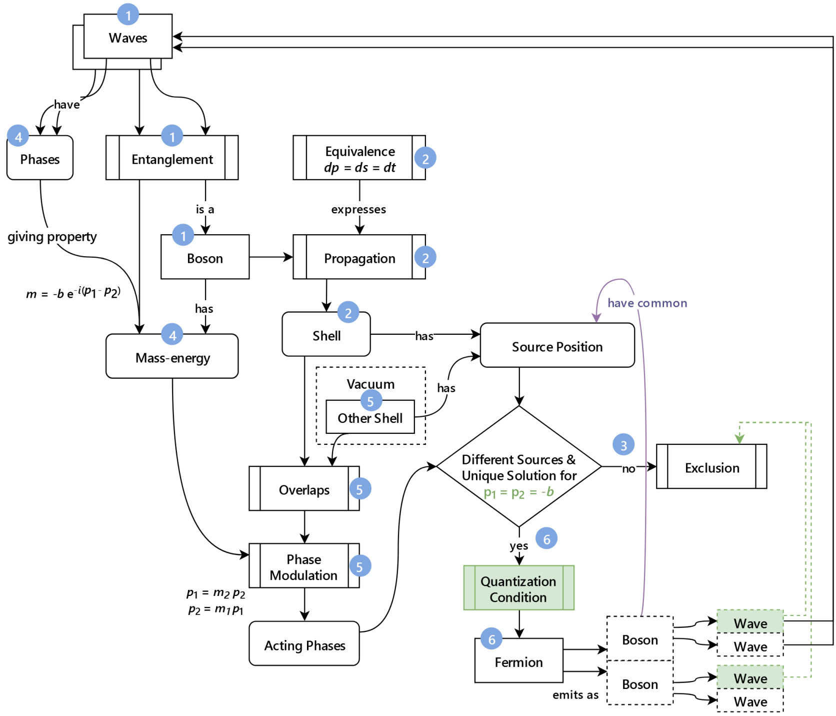

Fig. A.1. A process graph of the mechanism, annotated with rule numbers.

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